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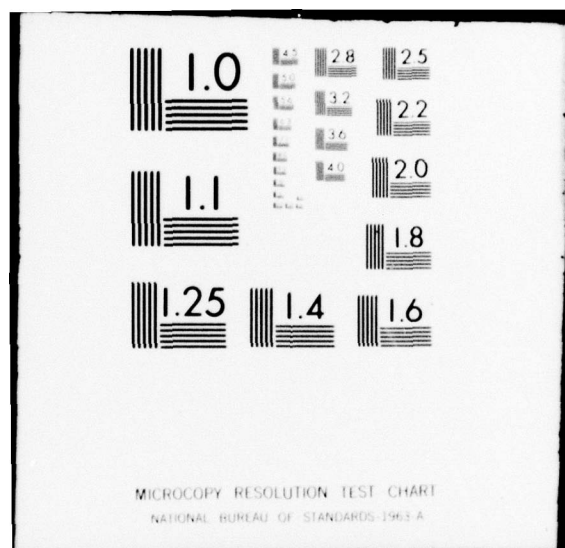
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Work done under the cited grant since preparation of an interim report dated 12/15/77 (the primary grant report) is described. The documented work consisted primarily of development of a GPSS simulation model for the radar network, which will be one of the major research tools used during continuation work under grant number 78-3619.

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FINAL REPORT ON
AFOSR MINIGRANT 77-3339
ADVANCED FORWARD AREA TACTICAL RADAR NETWORK
by
John Spragins

July 78

INTRODUCTION

This is a brief Final Report on work done on AFOSR Minigrant 77-3339, Advanced Forward Area Tactical Radar Network, since the work which was documented in an Interim Report on the research dated 15/12/77. As was stated in the Interim Report, the earlier report is the primary report on the Minigrant work, since it documents work done during the primary period of AFOSR funding (the summer of 1977). The continuation work leading to this Final Report has been at a greatly reduced level of effort, with zero salary support from AFOSR, either for the principal investigator or for the Ph.D. student, C. J. Warner, who did much of the work reported on here. (The principal investigator's time on the research during this phase of the effort was entirely time made available by the University under cost sharing, while Mr. Warner's time was time he had available in addition to time spent on work required for his appointment as a graduate teaching assistant and for his course work.) Despite the low level of support during the period reported on, work was done which should provide a good foundation for further work to be done under AFOSR renewal grant number 78-3619 (which is at an increased level of support). This report documents the further work done.

The primary aim of the work done during this interim period was to develop a GPSS simulation model of the radar network which could be used as a basis for studies to be conducted later. The model and the results of some initial runs obtained to verify its correct operation are discussed in the next section.

THE SIMULATION MODEL

A preliminary GPSS simulation program has been written for the advanced forward area tactical radar network. The program was written to model the network and its tactical environment. Briefly, the GPSS program models a grid of radar nodes over which simulated targets are flown. The targets are sighted and their tracks reported to the other nodes in the network. Tracking algorithms are used in the program to determine whether or not the tracks are to be reported to the rest of the network.

Valid arguments have been raised against this concept of trying to simulate targets actually flying over the network and applying tracking algorithms. For this reason, a second program is being written which will emphasize the communications protocols of the network and not attempt to simulate the tracking algorithms. This second program will use an expanded version of the communications portions of the first program, but will eliminate the portions which fly the targets over the network and which apply the tracking algorithms. These portions of the original program will be replaced by algorithms which simply generate messages for transmission according to any suitably chosen algorithm.

The communications protocols used in the preliminary program are designed to handle nondirected messages (i.e., track reports). The routing algorithm used is a form of flooding whereby when a node transmits a track report, it is sent to all of that node's neighbors except for the one from which the track report was received, with this algorithm intended to insure that each node in the radar network soon receives a copy of each report. The track reports are transmitted over completely synchronous, full duplex channels.

In order to verify the validity of the communications aspects of the preliminary GPSS program, several runs were made on the Oregon State Univer-

sity CYBER 70 computer system. No attempt was made to fully test the track-
ing portions of the model, and for this reason only a very simple target
pattern was used. Also for these runs, a rather small network was modeled,
as in shown in Figure 1 below. The traffic pattern and network size have no
bearing on the validity of the communications protocols and so these two
factors were chosen to keep computing costs to a minimum since no AFOSR sup-
port for computing costs was included in the Minigrant budget. The program
is capable of simulating much larger networks, however, and later runs will
use this capability.
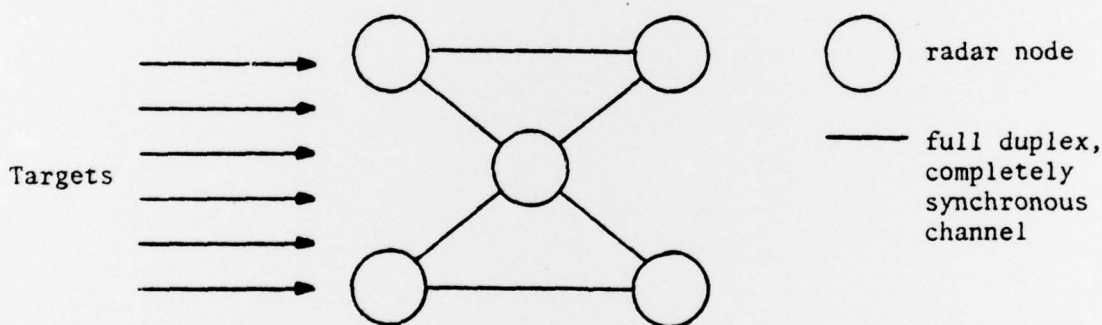
Figure 1

Targets were generated at the left edge of the network and flew straight
across it at a velocity of between 400 and 500 m/sec. Since the purpose of
these simulation runs was to test the communications protocols only and not
the tracking algorithms, the targets were only flown straight through the area
covered by the network. The targets are sighted by any of the radar nodes an
average of once every 47×10^{-4} seconds. (This number was derived from the
preliminary transmission load analysis and is only an approximate number. The
value of the number itself really does not matter, what does matter is the

ratio of this number to the channel service time, i.e., the amount of time needed to transmit one track report over the completely synchronous channels.) The channel service time was varied between 5×10^{-4} seconds and 150×10^{-4} seconds.

What should happen during the simulations is that soon after the target first enters the network area, it is sighted by a radar node which sends a track report on to its neighbors, which in turn send the report on to their neighbors until each of the nodes in the network has a copy of the report in its own file. (Each node in the network maintains a track report file which is printed out at the end of the simulation run.) For the purposes of the initial simulation runs, the files were allowed to hold up to 50 track records, and so only 50 targets were flown through the network. When any of the 50 targets is sighted a second time, no new track report is sent since the target will not have changed its course. What happens, then, is that when the targets first enter the network, a burst of track reports is generated. This burst of track reports dies out as soon as all of the nodes have track reports on each of the 50 targets. (Note that only the very first simulation runs made are documented here. Much more general types of message generation statistics will be simulated in later runs.)

The results of the simulation runs are summarized in Figures 2 through 6. These figures summarize the statistics of the twelve queues in the network (one queue was at the input to each communications channel). The statistics generated for each queue included its maximum length, the percentage of transactions (track reports) which spent no time in the queue, the average amount of time each transaction spent in the queue, and the average amount of time spent in the queue for those transactions which spent more than zero time in

the queue. Figure 2 gives a plot of the maximum of all 12 maximum queue lengths, and Figure 3 gives a plot of the average of all 12 maximum queue lengths. The actual numbers are not very significant, due to the highly approximate nature of the input data, but what is significant is that the shape of the plot is exponential as would be expected. Figure 4 gives a plot of the percentage of transactions which spent zero time in the queues. It is interesting to note that even at very short channel service times, up to 20% of the transactions had to spend time in the queues. This is a result of the channels being synchronized, with a transaction required to wait for the start of a slot even when there are no other transactions ahead of it. When this synchronization requirement was removed, the percentage of nonzero time transactions went to virtually 0%, as would be expected. Figures 5 and 6 give plots of the average time spent in the queues. Again, the actual values are not significant, but what is significant is that they properly show exponential curves.

As was previously stated, in addition to the queue statistics, the track file of each node was printed out. These files are not reproduced here, but they did show that the track reports were successfully being routed to all the nodes in the network, thus indicating that the routing algorithm worked for the extremely simple cases studied.

As can be seen, the simulation runs are consistent with basic queueing principles and appear to validate the simple communications protocols used. This program will provide a basis for a second program which will be designed to test the performance of various communications protocols, for both directed and nondirected messages, which are designed specifically for operation of a radar network.

Fig. 2

Max Max Queue Length VS. Channel Service Time
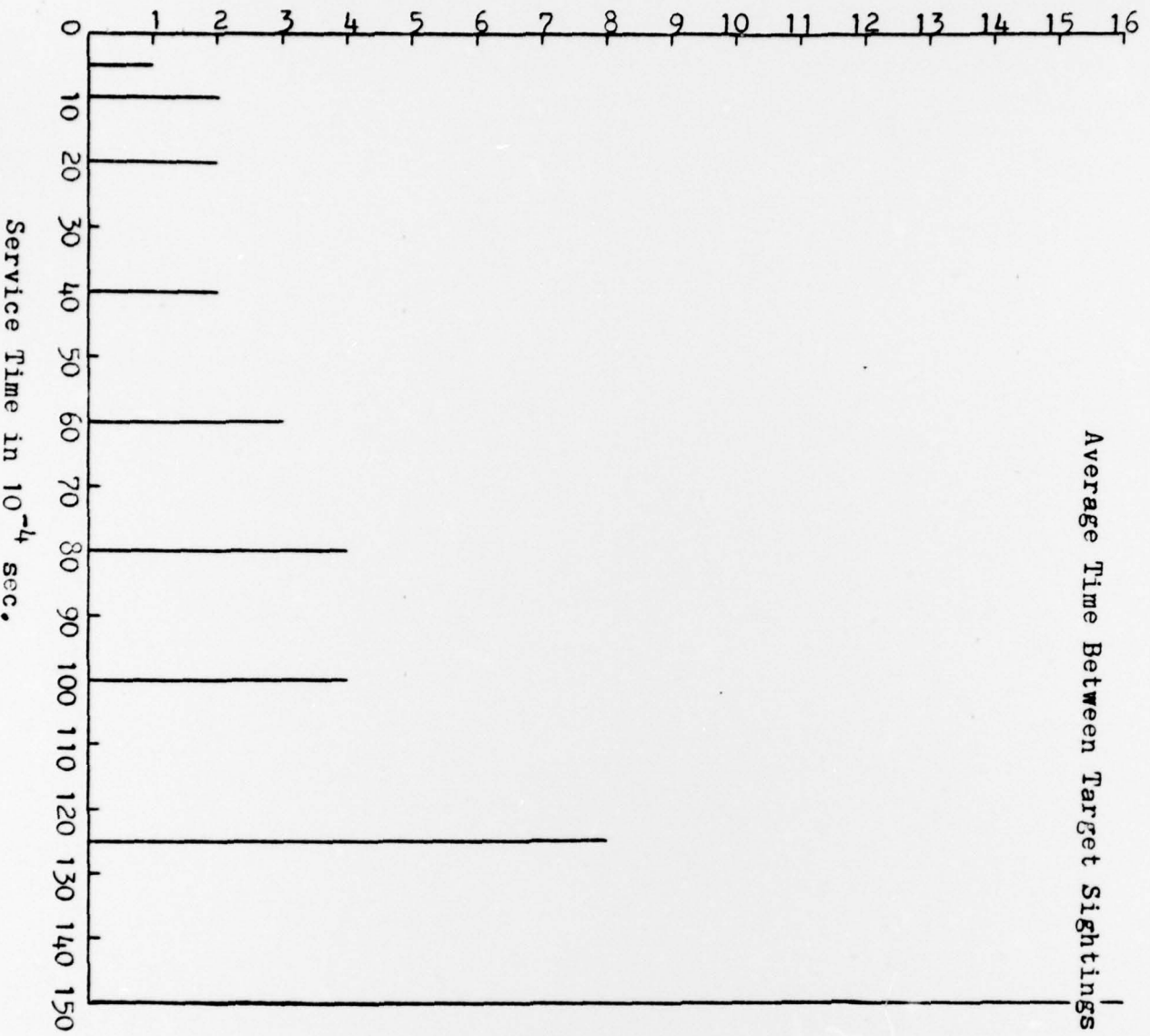
Average Time Between Target Sightings = 47 x 10⁻⁴ sec.

Fig. 3

Agerage Max Queue Length VS. Channel Service Time
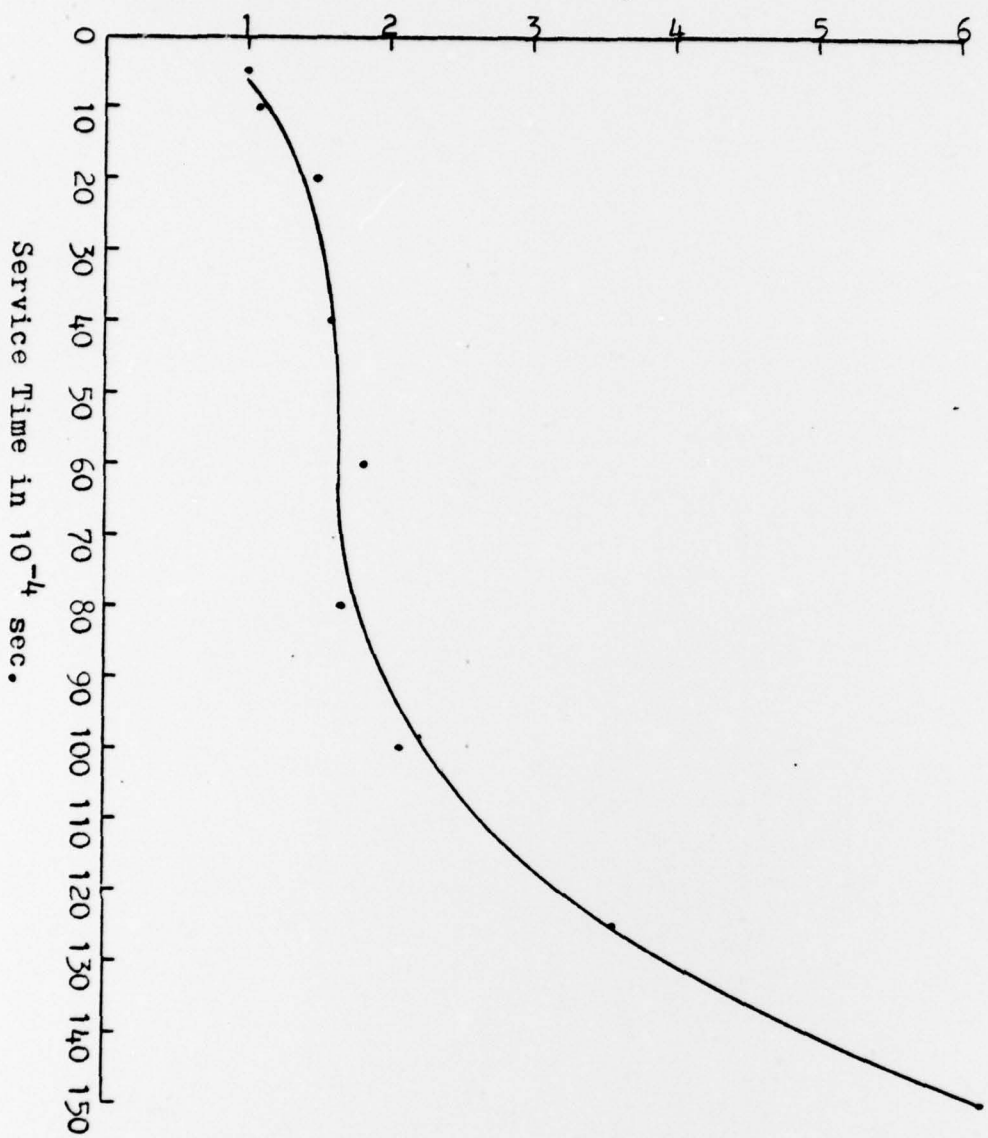
Average Time Between Target Sightings = 47 x 10^{-4} sec.

Fig. 4

Percentage of Track Reports Spending Zero Time in Queues VS. Channel Service Time

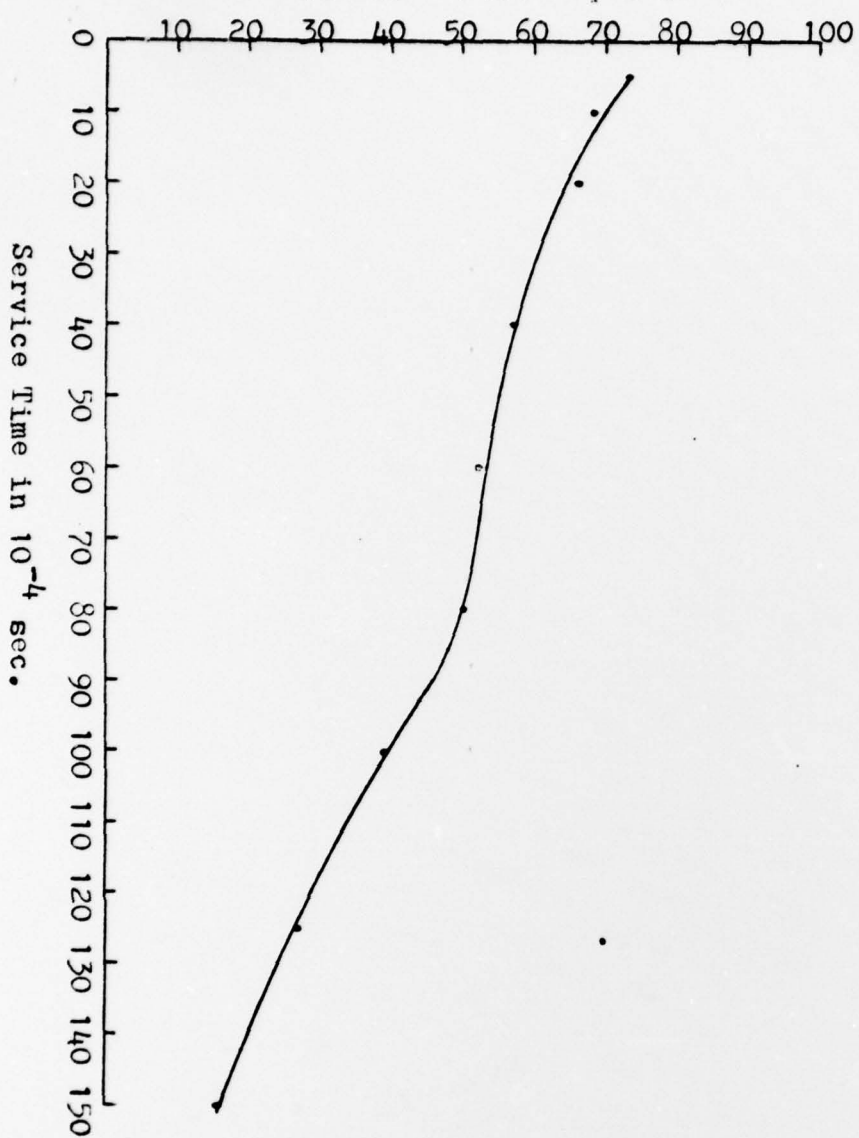Average Time Between Target Sightings = 47 x 10^{-4} sec.

Fig. 5

Average Time Spent in Queues VS. Channel Service Time

Average Time Between Target Sightings 47 x 10^{-4} sec.

Fig. 6
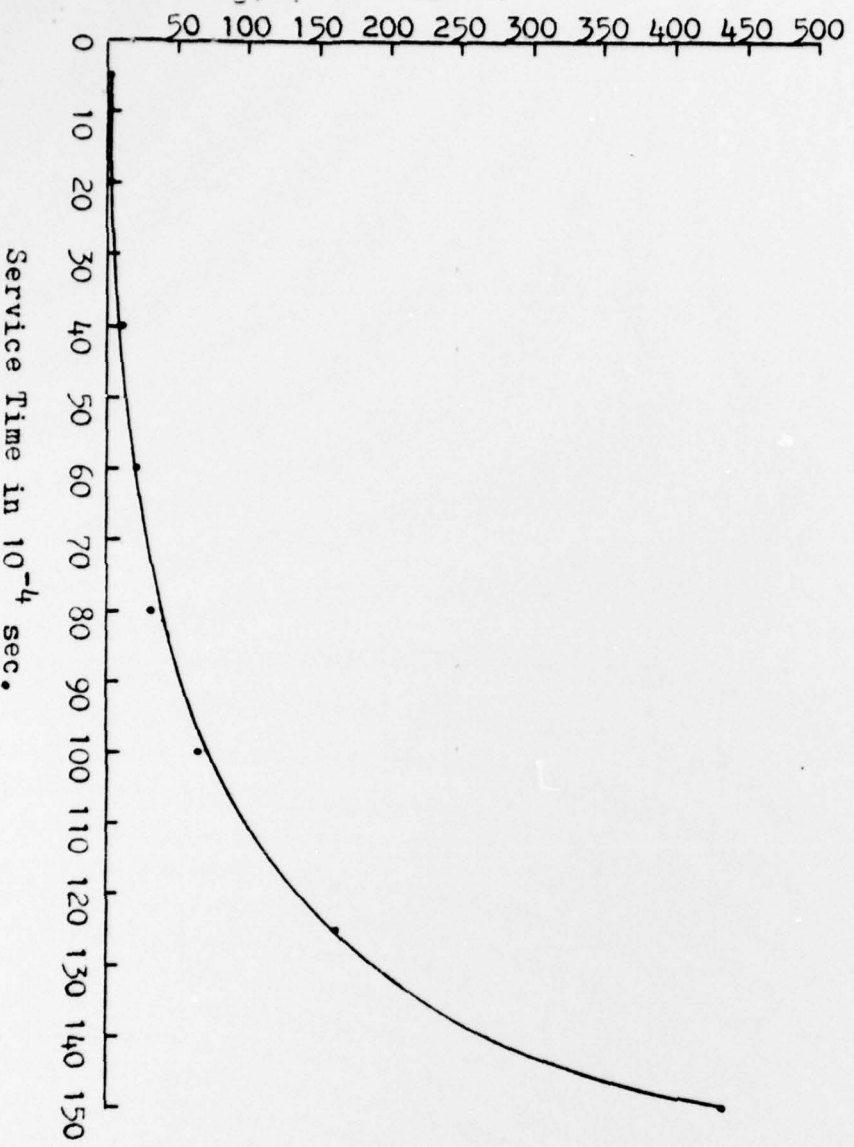
$Average Time Spent in Queues VS. Channel Service Time

$Average Time   Average Time Per Transaction Excluding
                 Transactions Which Spent Zero Time in
                 the Queues.

Average Time Between Target Sightings = 47 x 10⁻⁴ sec.

Service Time in 10⁻⁴ sec.